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1. Introduction

In this assignment, we will study dementia by analyzing Magnetic Resonance Imaging (MRI) data. We aim to utilize a subset of data from a longitudinal study, 'INF2178_A4_data.csv', focusing on comparing the changes within individuals over time between patients with and without dementia.

Our exploration will address two fundamental research questions as insights into revealing the effects of dementia on the brain:

Research question 1: How do gender and the number of visits affect nWBV?

Research question 2: How do the MMSE scores get affected by different subject groups and the number of visits?

I will explore these research questions through two different models.

2. Data Cleaning and Data Wrangling

This original dataset has 16 columns and 294 entities (rows). To better analyze the research, we have adjusted the original dataset: Since our analysis is quantitative in nature, I have considered keeping the following to make the data clearer and easier to understand: 'Subject ID', 'Group', 'Visit', 'M/F','MMSE', 'nWBV'.

Thus, based on the statistical summary of the data:

The dataset has a total of 294 entries with 6 features.

One feature is recognized as integer type (int64), 2 features are recognized as float types, 3 features are recognized as object types.

There is one missing values in MMSE, I will use the mean value to fill in the null value of MMSE.

3. Exploratory Data Analysis

Figure1 shows how the standardized whole brain volume of subjects in different gender with the number of visits that between the two visits. There is a downward trend in nWBV for both males and females, with a particularly noticeable decrease in females during the second visit, which narrows the gap between the two genders; moreover, the error bars are relatively longer in the second visit, indicating a greater degree of internal variability.

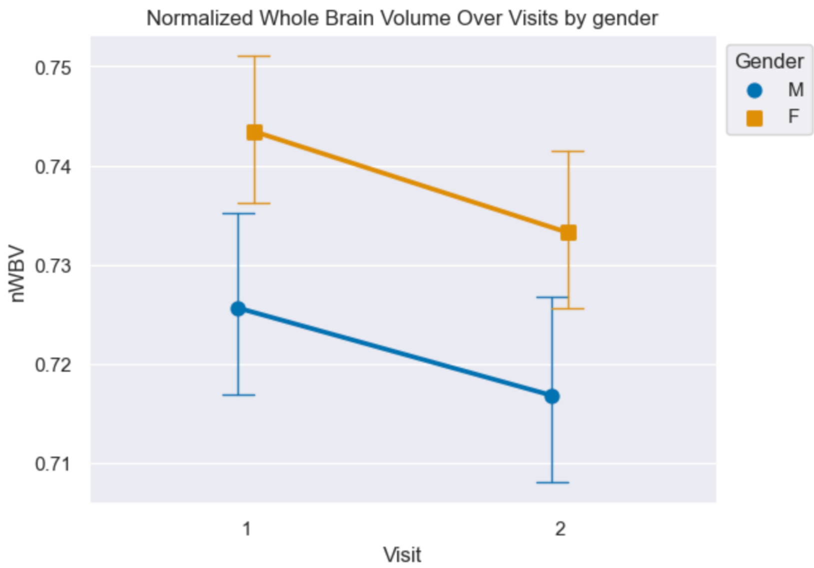

Figure 1

Figure 2 shows how the Mini Mental State Examination Score of subjects in different group with the number of visits. For the MMSE scores, the 'Nondemented' group experienced a slight decrease, while the 'Demented' group and the 'Converted' group showed significant declines. Additionally, the 'Demented' group and the 'Converted' group displayed larger error bars during the second visit, indicating increased internal variability within these groups.

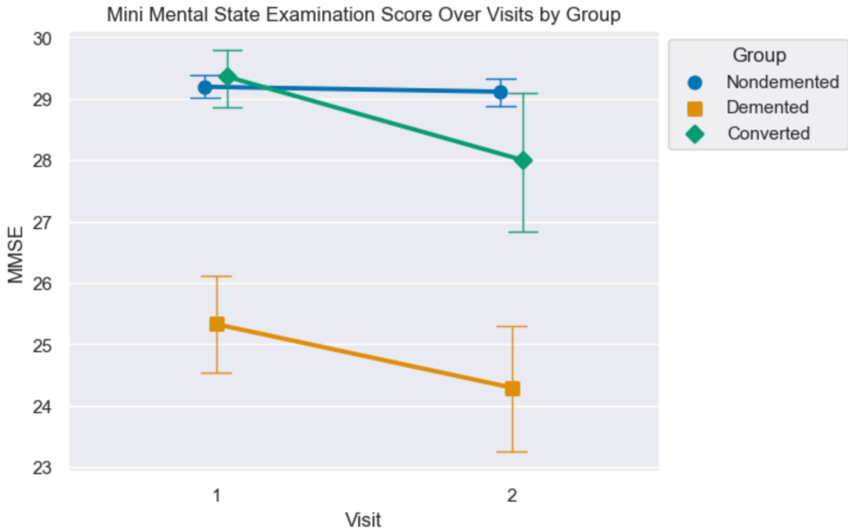

Figure2

4. Mixed-Effects ANOVA

4.1 Mixed-design ANOVA Model 1 Assumption

For Gender, H0: There is no difference in nWBV among the different gender.H1: There is a difference in nWBV between genders.

For Visit, H0: There is no change in nWBV across the different visits.H1: There is a change in nWBV following at least one visit.

For the Interaction effect (Group*Visit), H0: There is no interaction effect of gender and visit on nWBV.H1: There is an interaction effect of gender and visit on nWBV.

Source	SS	DF1	DF2	MS	F	p-unc	np2	eps
M/F	0.021	1	142	0.021	8.030	0.005	0.054	nan
Visit	0.007	1	142	0.007	93.305	<0.001	0.397	1.000
Interaction	<0.001	1	142	<0.001	0.621	0.432	0.004	nan

Table 1

For the Table 1, the gender effect shows F=8.030, p=0.005<0.05, indicating that we have sufficient evidence to reject the null hypothesis, i.e. there is no difference in nWBV between the different gender. The visit effect shows F=93.305, p<0.001, indicating that we have sufficient evidence to reject the null hypothesis, i.e. there is no change in nWBV across the different gender. The interaction effect (Gender*Visit) shows F=0.621, p=0.432 > 0.05, indicating that we do not have sufficient evidence to reject the null hypothesis, i.e. there is no interaction effect of gender and visit on nWBV. Eps: was used for the Mauchly's test for the visit effect, which yielded a result of 1.000, implying that the assumption of homogeneity of variances is satisfied.

Contrast	Visit	A	B	Paired	Parametric	T	dof	alternative	p-unc
Visit	-	1	2	True	True	9.672	143	two-sided	<0.001
M/F	-	F	M	False	True	2.821	122.930	two-sided	0.006

Visit * M/F	1	F	M	False	True	2.974	124.056	two-sided	0.004
Visit * M/F	2	F	M	False	True	2.608	122.876	two-sided	0.010

Table 2

I selected some important values from the results of the post hoc test to create Table 2.The Table 2 shows that for between visits, the p-value is less than 0.001, indicating that we have sufficient evidence to reject the null hypothesis, which suggests that there is a significant change in nWBV between the two visits. Between genders, the p-value is less than 0.05, indicating that there is a significant difference in nWBV between genders. For the interaction effect between genders at Visit 1 and Visit 2, the p-value is less than 0.05, indicating that the influence of gender and number of visits on nWBV is not independent but interactive.

4.2 Mixed-design ANOVA Model 2 Assumption

For Group, H0: There is no difference in MMSE scores between the different groups of subjects.H1: There is a significant difference in MMSE scores between at least two groups of subjects.

For Visit, H0: There is no change in MMSE scores across the different visits for subjects.H1: There is a significant change in MMSE scores at least following one visit for subjects.

For the Interaction effect (Group*Visit), H0: There is no interaction effect between group and visit on MMSE scores. H1: There is a significant interaction effect between group and visit on MMSE scores.

Source	SS	DF1	DF2	MS	F	p-unc	np2	eps
Group	1322.017	2	141	661.009	56.100	<0.001	0.443	nan
Visit	21.528	1	141	21.528	8.525	0.004	0.057	1.000
Interaction	16.204	2	141	8.102	3.208	0.043	0.044	nan

Table 3

For Table 3, the group effect shows F=56.100, p<0.001, indicating that we have sufficient evidence to reject the null hypothesis, i.e. there is no difference in MMSE scores between the different groups of subjects. The visit effect shows F=8.525, p<0.05, indicating that we have sufficient evidence to reject the null hypothesis, i.e. there is no change in MMSE scores across the different visits for subjects. The interaction effect (Group*Visit) shows F=3.208, p<0.05, indicating that we have sufficient evidence to reject the null hypothesis, i.e. there is no interaction effect between group and visit on MMSE scores. Eps: was used for the Mauchly's test for the visit effect, which yielded a result of 1.000, implying that the assumption of homogeneity of variances is satisfied.

Contrast	Visit	A	B	Paired	Parametric	T	dof	alternative	p-unc
Visit	-	1	2	True	True	2.876	143	two-sided	0.005
Group	-	Converted	Demented	False	True	6.745	50.480	two-sided	<0.001
Group	-	Converted	Nondemented	False	True	-1.303	12.315	two-sided	0.216
Group	-	Demented	Nondemented	False	True	-9.512	65.514	two-sided	<0.001
Visit * Group	1	Converted	Demented	False	True	8.076	60.165	two-sided	<0.001
Visit * Group	1	Converted	Nondemented	False	True	0.489	13.999	two-sided	0.633

Visit * Group	1	Demented	Nondemented	False	True	-9.124	68.185	two-sided	<0.001
Visit * Group	2	Converted	Demented	False	True	4.515	33.372	two-sided	<0.001
Visit * Group	2	Converted	Nondemented	False	True	-1.816	11.802	two-sided	0.095
Visit * Group	2	Demented	Nondemented	False	True	-8.480	66.145	two-sided	<0.001

Table 4

I selected some important values from the results of the post hoc test to create Table 4. From the Table 4, the comparison between visits shows a p-value < 0.05, indicating that there is a significant change in MMSE scores with the number of visits. The comparison between different groups reveals significant differences in MMSE scores between the 'Demented' group and both the 'Nondemented' and 'Converted' groups with a p-value<0.001. The comparison of the interaction effect between group and number of visits shows that there is a significant interaction between the 'Demented' group and both the 'Nondemented' and 'Converted' groups with a p-value<0.001.

5. Statistical Power Analysis Plot

The figure 3 shows that with the given parameters, the required sample size for each group is 45.451. This means that to achieve a statistical power of 91% and to detect an effect size of 0.7, each group would need at least about 46 samples; moreover, the curves for effect sizes clearly demonstrate that an increase in sample size has a significant impact on increasing the power of the test.

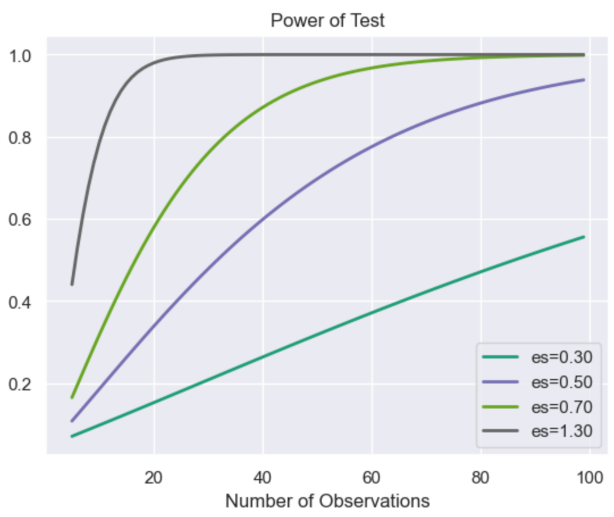

Figure 3